DESIGN AND CONSTRUCTION OF THE AKABUCHIGAWA BRIDGE - PRESTRESSED CONCRETE BOX GIRDER BRIDGE WITH CORRUGATED STEEL WEBS AND PRE-CAST RIBS -

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ABSTRACT

Akabuchigawa Bridge on the New Tomei Expressway is located near Mt. Fuji in Shizuoka Prefecture, and is a 6+5 spans continuous prestressed concrete box girder bridge with corrugated steel webs having the total length of 885 meter. Since the bridge was constructed over the deep valley area, the possible locations for the piers were limited. As results, the bridge has various lengths of spans. Considering these conditions, some rationalized erections methods were performed with the effective use of corrugated steel webs and pre-cast concrete elements in order to enable labor saving and rapid construction in cantilever erection method. The use of corrugated steel webs and pre-cast elements could also reduce the number of assembling and dismantling of moving vehicle as well as labor saving both in the cantilever erection and the center and the side closures.

1. INTRODUCTION

The New Tomei Expressway is currently under construction as a national highway construction project. Its objective is to improve the durability of the Tomei Expressway, Japan's most important road transport network. Akabuchigawa Bridge is (6+5)-span continuous PC box girder with corrugated steel web of 885m in length of the bridge, and is composed of the west bridge spanning the rural road and the east bridge spanning the Akabuchi River. Since the bridge was constructed over the deep valley area, the possible locations for the piers were limited. As results, the bridge has various lengths of spans. The bridge performed the rationalized construction by effective use of corrugated steel webs as erection girders in order to enable labor saving and rapid construction of cantilever erection. As a result, the use of corrugated steel webs as erection girders could reduce the number of assembling and dismantling of moving vehicle, labor saving support of the side span and cantilever erection.

The bridge is the box girder with corrugated steel webs using pre-cast concrete members and having the maximum span of more than 100m. Since the deflection of main girder was heavily affected with the change of temperature everyday, it was the important issue to control the camber correctly during cantilever erection. So the deflection of daily changes by the temperature difference of slab was paid its attention to, and camber controls in cantilever erection and quantitative control of a closure condition of corrugated steel web were enabled because the measurement results were done quantification. Photos 1 and 2 show a full view of the Akabuchigawa Bridge.

This paper will cover the design and construction of the Akabuchigawa Bridge, focusing rationalization construction in cantilever erection and deflection management in upper and bottom slab temperatures fluctuate.

Photo.1 Full view of the Akabuchigawa Bridge

Photo.2 Full view of the Akabuchigawa Bridge

2. THE AKABUCHIGAWA BRIDGE ON THE NEW TOMEI EXPRESSWAY

The following is an overview of the Akabuchigawa Bridge. Refer to Fig.1 for a general view of the bridge, Fig.2 for a cross section of main girders, and Tab.1 for the quantities of the main materials.

Project name: New Tomei Expressway Akabuchigawa Bridge PC Superstructure Westbound Construction Project
Commissioned by: Tokyo Bureau, Central Nippon Expressway Co.,Ltd.
Location: Makado to Hina, Fuji-City, Shizuoka Prefecture (Japan)
Project term: Oct.2004-Nov.2008
Structural mode: (West bridge) 6-span continuous PC box girder with corrugated steel web
(East bridge) 5-span continuous PC box girder with corrugated steel web
Design load: B live load
Bridge length: (West bridge) 404.0m
(East bridge) 481.0m
Span length: (West bridge) 41.0+56.0+82.0+92.0+82.0+48.8m
(East bridge) 99.55+115.0+80.0+92.5+91.3m
Effective width: 16.5m

The load bearing ground has been each different from the bridge in the east and west bridge. On this account the spread foundation was employed with west bridge mainly, and a large-diameter caisson type piles was employed with east bridge. The P7 pier, with maximum height of 58.7m, adopted the steel pipe concrete composite structure (hybrid structure).

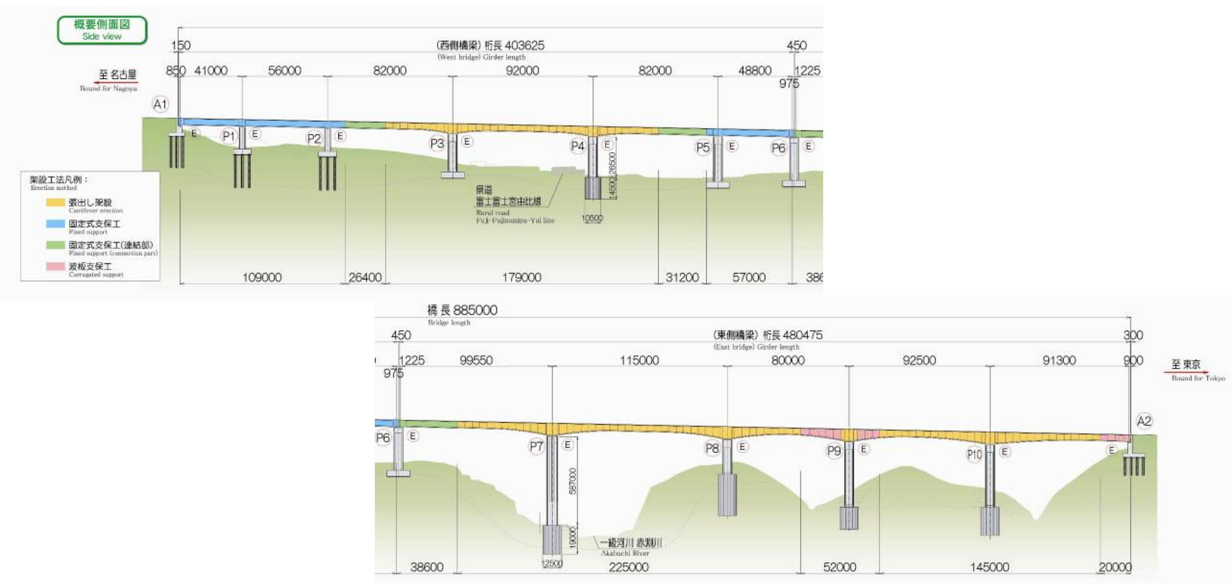

Fig.1 General View of the bridge

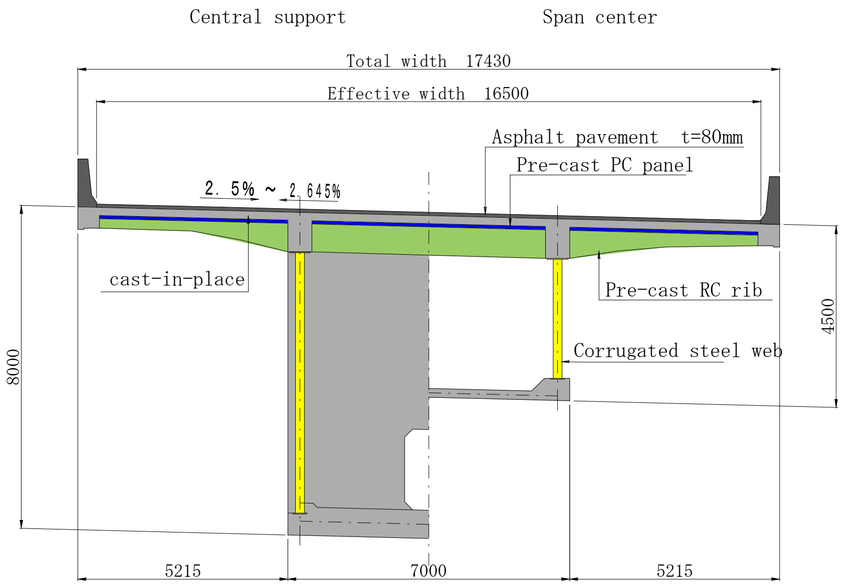

Fig.2 Cross section of main girders

Tab.1 Quantities of the main materials

		Unit	Quantities	Specification
Concrete		m³	10,304	σck=40N/mm2
Formwork		m²	18,043	
Rebar		t	2,505	SD345
PC strand	12S15.2	kg	6,041	SWPR7B
	19S15.2	kg	211,699	SWPR7B
	27S15.2	kg	241,025	SWPR7B
	1S21.8	kg	80,590	SWPR7B
Corrugated steel		t	948	SM400,SM490,SM490Y
RC rib		rib	366	σck=50N/mm2
PC panel		panel	6,064	σck=50N/mm2

3. AKABUCHIGAWA BRIDGE'S CHARACTERISTIC

In the bridge, to reduce the cost and to shorten the construction period adopted the rationalization construction that using the corrugated steel web for erecting members(Photo-3). The bridge secured the rigidity of the girder by jointing upper and lower flanges of corrugated steel web after precedence erection of corrugated steel web. Then, it is a method of preceding execution of the bottom slab after moving the moving vehicle on the flange of corrugated steel web.
Moreover, to attempt the rationalization construction of the upper slab, pre-cast members (RC rib and PC panel) were adopted. Concretely, the labor saving of construction is attempted by erecting pre-cast RC rib on the flange of the corrugated steel web, erecting PC panel between RC ribs, and erecting the concrete of the cast-in-place on that in addition. Photos 4 and 5 show erecting of the RC rib and PC panel, Photo 6 shows cantilever erection status.

It tried to save labor in the following points in this bridge.

(a) Labor saving of cantilever erection
(b) Reduce the number of assembling and dismantling of traveler for cantilever erection
(c) Labor saving construction in side span closure

Photo.3 Erection of corrugated web

Photo.4 Erecting of RC rib

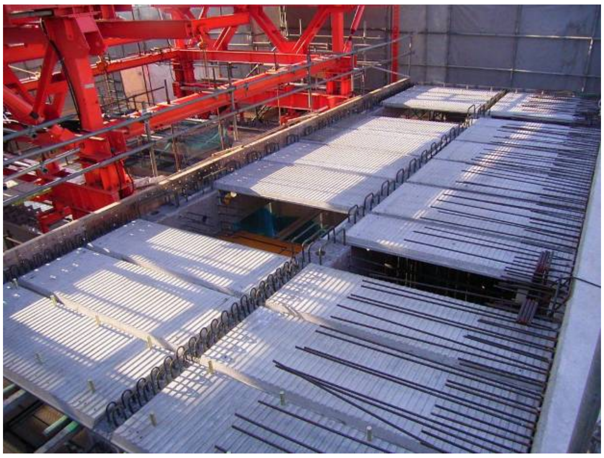

Photo.5 Erecting of PC panel

Photo.6 Cantilever erection status

4. DESIGN

(1) Design of The Upper Slab

The bridge had the slab with the rib supported by two directions (the corrugated steel web and the pre-cast ribs). Therefore, the slab was designed by three-dimensional FEM analysis. An analytical model considered discontinuity in the bridge axis right-angled direction of the PC panel. This structure has the feature that the rigidity in the bridge axis right-angled direction improves and the requirement of PC cable in slab decreases in comparison with the general slabs.

(2) External Cable Structure

The bridge used PC strands covered by epoxy resin. This achieves weight reduction and labor saving while making the most of the advantages of external cables. The double pipe method is employed for the anchorages, which is a solution for easier future replacement.

(3) Lighting Installation in Box Girder

In the bridge, lighting installation was installed to maintain in box girder (Photo 7). It was assumed that in box girder lighting installation got the illumination intensity which was necessary for outline inspection, and it was assumed that details inspection was done by the flashlight. The illumination photometry was executed in box girder, and it was done with the illumination intensity which the letter could distinguish. The lighting installation arranged between cross beams, and electric energy of the lighting installation was decided depending on

Photo.7 Lighting installation

distance between cross beams. In addition, power consumption was small, and the lighting installation used the LED lamp that exchange was unnecessary in comparison with the fluorescent lamp in the long term.

5． LABOR SAVING OF A CANTILEVER ERECTION

（1） Moving Vehicle

Moving vehicle in the conventional method requires the rail equipment on the constructed bridge deck, and supporting worktable of a state of forward thrust. In this method, rails for moving vehicle are installed on the flange of the corrugated steel web, and moving vehicle is arranged. Moreover, it became possible to decrease the equipment weight because it was assumed that it was structural hanging the worktable perpendicularly (58% reduction). Fig.3 shows a comparison of this method and conventional method.

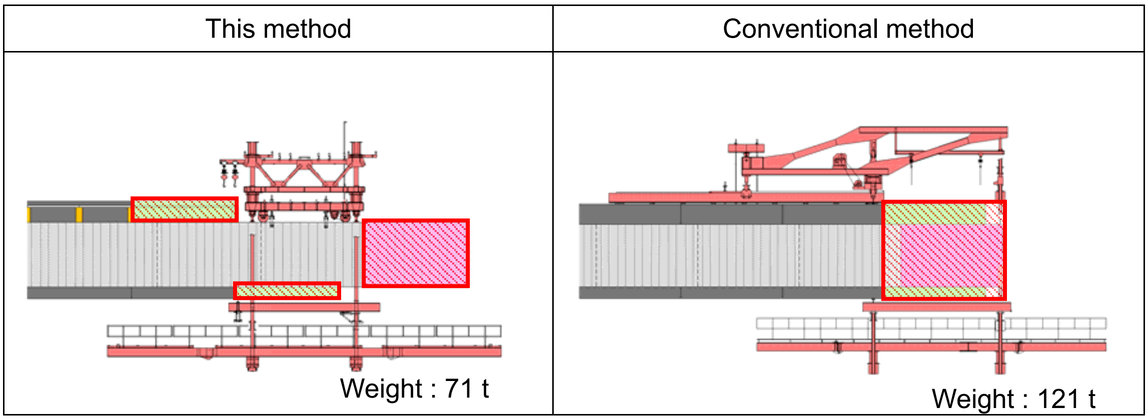

Fig.3 Comparison of moving vehicle

（2） Steps of Cantilever Erection

Fig.2 shows the construction steps.

STEP1: moving of the moving vehicle to n block after prestressing

STEP2: In n-1 block, erection of the RC ribs in the upper slab. In n Block, assembly of re-bars in the bottom slab. In n+1 block, the corrugated steel webs are erected

STEP3: In n-1 block, erection of the PC panels, assembly of re-bars and PC strands in the slab. In n+1 block, welding of corrugated steel web.

STEP4: Concrete casting, insertion of external cables and prestressing

The slab work became upper and lower work in the same block and it was critical in the conventional method so far on the process. In this method, the efficiency improvement of work is attempted from can the decentralization of the work part to three blocks and becoming of the construction of the upper and bottom slabs simultaneously possible. As a result, shortening at the construction cycle became possible.
Moreover, because the bridge adopted the external cable structure, using PC strands covered by epoxy resin, a lot of reinforcing bars are arranged near the anchorage of external cables for cantilever erection. These works took time very much, and were critical on the process. Then, the labor saving and making to rapidity were attempted by external cable anchorages are placed inside the pre-cast ribs in this method (Fig.5, Photo.8).
In addition, the cables could be drawn into straight line by arranging the cable drum on the corrugated steel webs, and I was safe, and smooth works were enabled in this method (Fig.6).

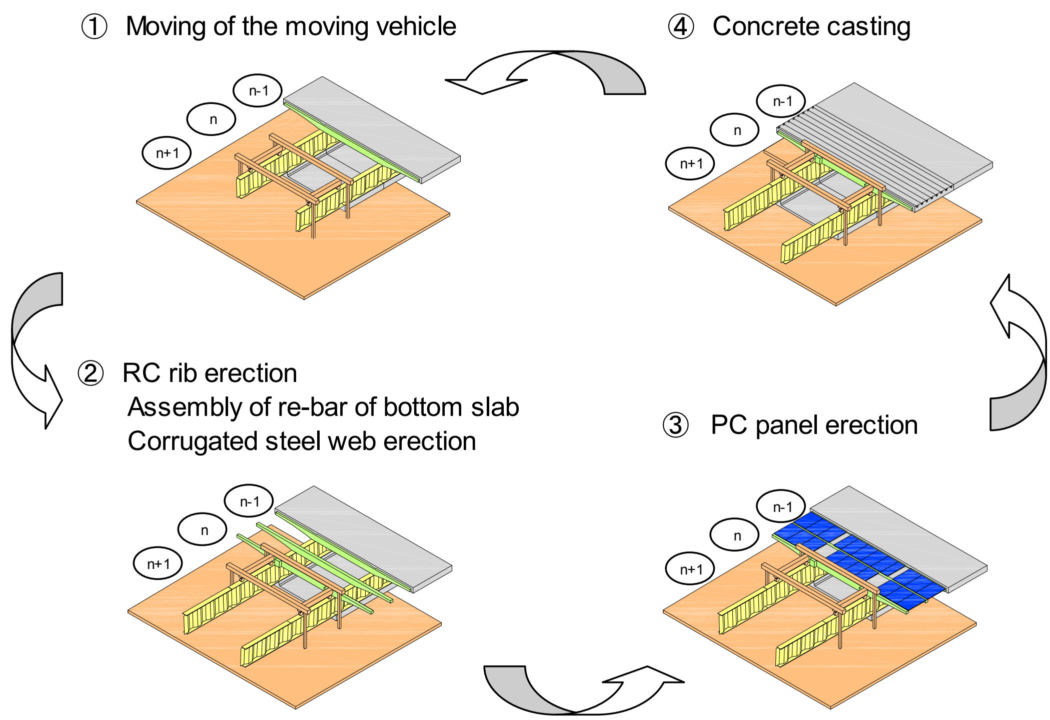

Fig.4　Construction process of cantilever erection

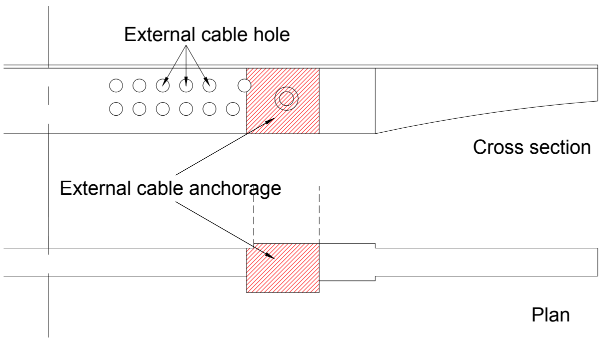

Fig.5 Overview of RC rib

Photo.8 RC rib

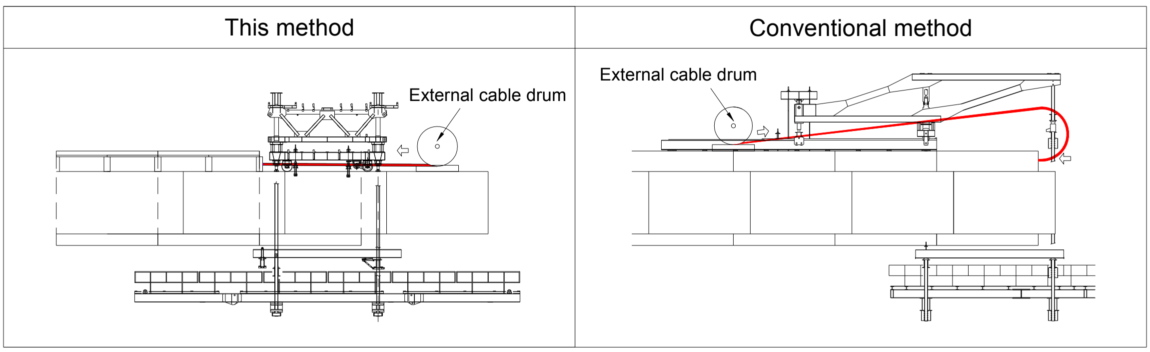

Fig.6　Comparison of cable installation

６． REDUCE THE NUMBER OF ASSEMBLING AND DISMANTLING OF TRAVELER FOR CANTILEVER ERECTION

The range of cantilever erection from P9 pier is short and unbalanced because of selection of span length (Fig.7). The range of cantilever erection balance with the assembling / dismantling of the moving vehicle isn't become, and it is the non-efficiency. Thus movement enabled the moving vehicle for an adjacent pier by precedence erection of the corrugated steel web, the establishment to P9 pier was done.
The closure length of the corrugated steel web of P8 side had 14.45m, and it was difficult that it was erected once. On this account the bracket staging was used, and the corrugated steel web of 9.65m that did a field assembling after P9 column capital construction beforehand was erected by the crane. Length of a closure the corrugated steel web between P8-P9 became 4.8m in this, and quality control of erection was done by erecting it on the moving vehicle if easy. In addition, the temporary members were installed between the corrugated steel webs in construction, and rigidity of cross direction was got (Photo.9). By these, the dismantling / transportation / assembling of the moving vehicle could be omitted, and construction period shortening for about 1 month was enabled (Fig.8 Photo.10).

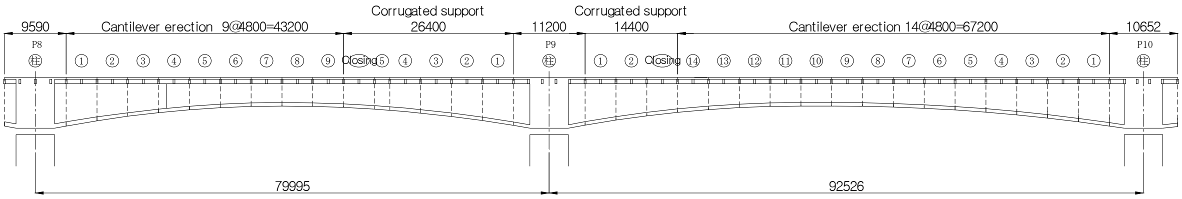

Fig.7 Side view of P8-P9-P10

Photo.9 Erection of corrugated steel web in P9

Photo.10 Closing corrugated steel web in P9

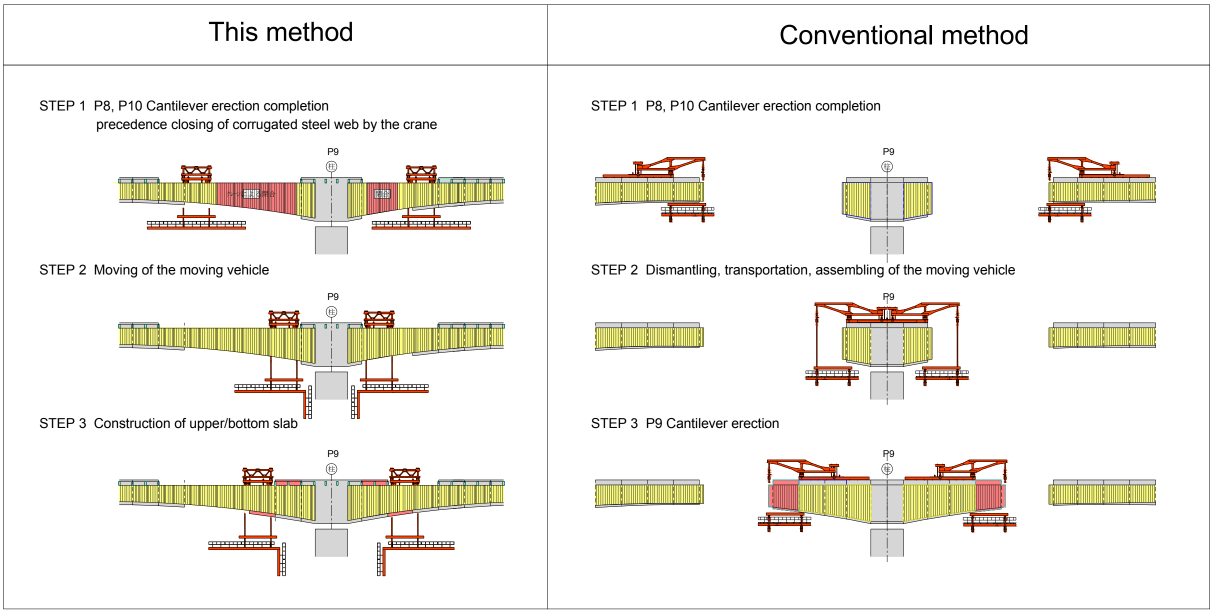

Fig.8 Comparison of erection in P9

7. LABOR SAVING CONSTRUCTION IN SIDE SPAN

(1) Construction Outline

The topography in front of an abutment pier was steep, as for side span (P10-A2), erection by the fixed support was difficult (Fig.9). In addition, because side span length was long with about 20m, the following general construction method was thought about, but increase of the construction cost and increase of the construction days were expected both.

a) The establishment of the intermediate supports by caisson type piles

b) Use of large erection members

c) Addition of the non-symmetric cantilever erection in P10

So precedence closure did the corrugated steel web after constructed the work at A2 end support part, and a precedence closure done the corrugated steel web was used of as stiffening girder, and side span constructed (Fig.10).
By this method, large construction members weren't required, and labor saving erection and cost reduction were enabled (Tab.2). By this method, large construction members weren't required, and labor saving erection and cost reduction were enabled.

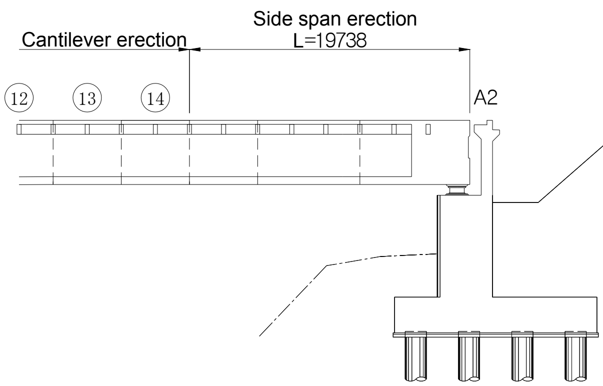

Fig.9 Side view of side span(P10-A2)

Tab.2 Comparison of erection of steel weight

Erection of steel weight		Materials
This method	30t	H-beam
Conventional method	91t	Truss-beam

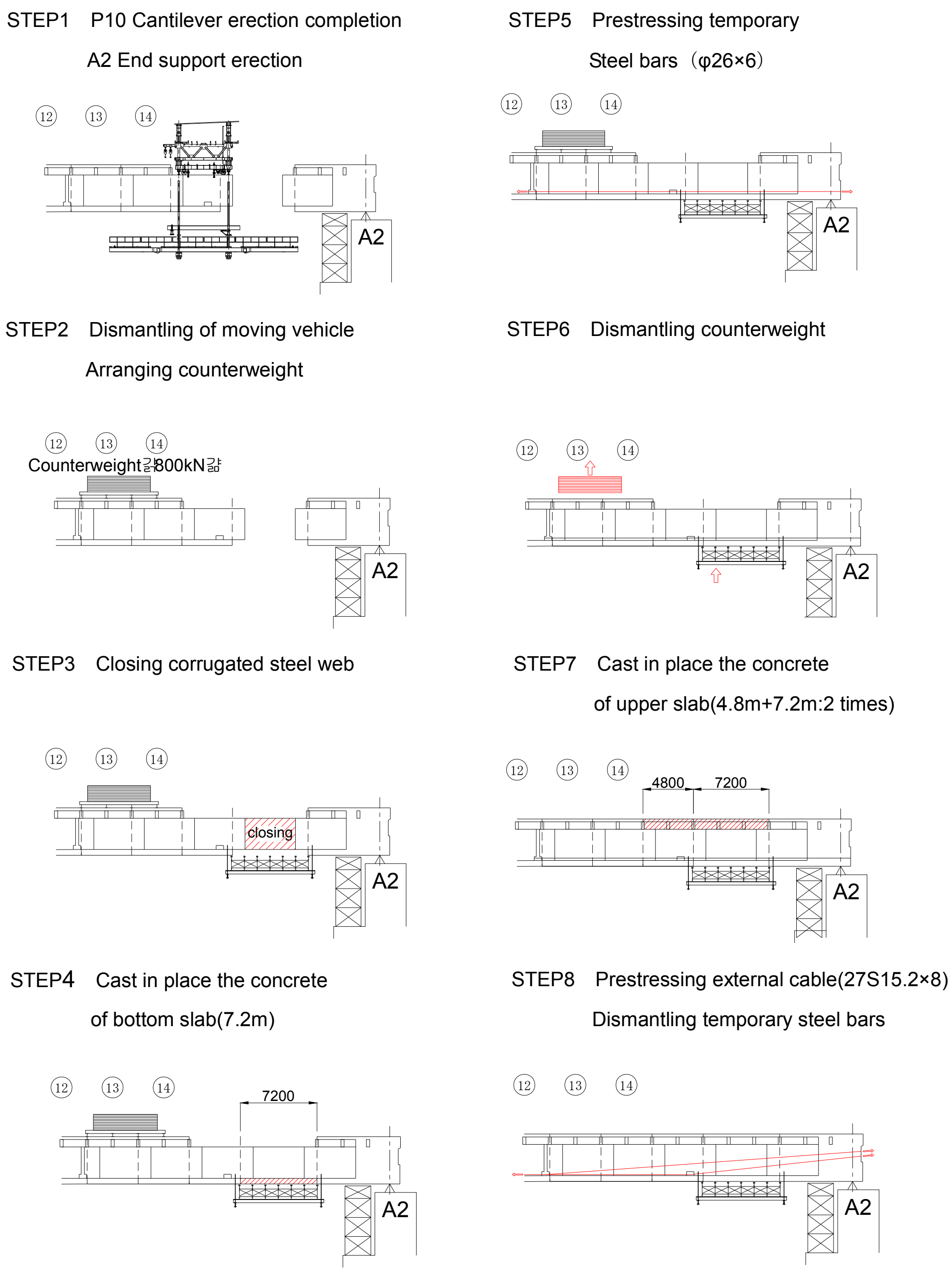

Fig.10 Construction process of side span

（2）Construction Method of End Support (A2)

In this bridge, while P10 cantilever erection had been done, precedence of A2 end support part executed the work.
The following two points of advantages are given by this.

a) Process shortening: Shortening of the total process due to precedence erection.

b) Displacement control: Because P10 cantilever length is long with 67.2m, it is prevention of plastic deformation by a long-term closure waiting.

（3） Construction of Upper Slab

In upper slab cast in place the concrete of closure block, compression stress of upper flange and tensile stress of bottom slab exceeded allowable stress.
On this account the following two supporting methods of construction were used.

a) Prestressing temporary cable (temporary cable : Φ26×6)

b) Artificial prestressing by removal of counterweight

Improvement of tensile stress to occur when cast in place the concrete of upper slab by temporary steel bars which arranged in bottom slab could be planned, but compression stress to occur in upper flange only temporary steel bars couldn't be controlled in allowable stress. On this account the rebound effect by removal of counterweight was used, and compression stress of flange and tensile stress of bottom slab was improved.

8． INFLUENCE BY TEMPERATURE DIFFERENCE OF SLAB

（1） Measurement Method

The measurement temperature difference of upper and bottom slab used datelogger and thermocouple. Fig.11 shows measurement point. The thermocouple of an upper slab arranged in the middle of slab thickness in order to avoid influence of a temperature change of the concrete surface by the sunshine.

（2） Measurement Result

Because influence of the seasons (outside temperature) were thought about, the measurement of the temperature difference of slab adjusted it to construction progress, and it was constructed in each of the summer / the winter. Tab.3 shows measurement result.
The deflection of the girder tip in a summer measurement almost agreed with the calculation. (Maximum 23mm (Fig.12)). In addition, the temperature difference of slab and the deflection were able to confirm that they didn't occur by rainy weather when there wasn't influence of the sunshine. Furthermore, it was sprinkled in fine weather at the bridge deck in order to control the deflection by a temperature difference of slab, and the temperature difference of slab and girder deflection were measured. As a result, it was recognized about 50% deflection could be reduced by bridge deck sprinkling and that convergence time of the deflection could be shortened. It was recognized that the joining of a the corrugated steel web (= welding time) in the state that there wasn't a deflection could be grasped by this quantitatively.

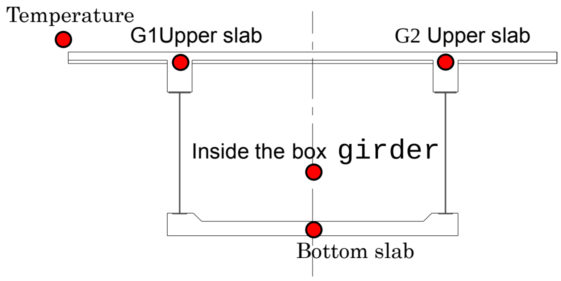

Fig.11 Measurement points

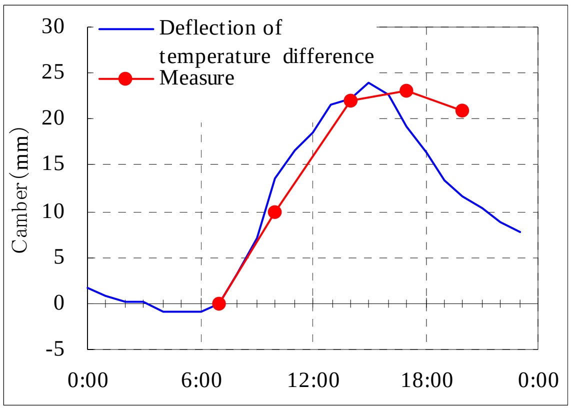

Fig.12 Deflection history of girder edge

Tab.3 Measurement results

Measurement time	Maximum temperature difference of slab		Minimum temperature difference of slab		Maximum deflection
	Temperature difference	Time Occurred	Temperature difference	Time Occurred	
Summer construction	7℃	15 : 00	0℃	6 : 00	23mm
Winter construction	1.2℃	12 : 00	0℃	8 : 00	7mm

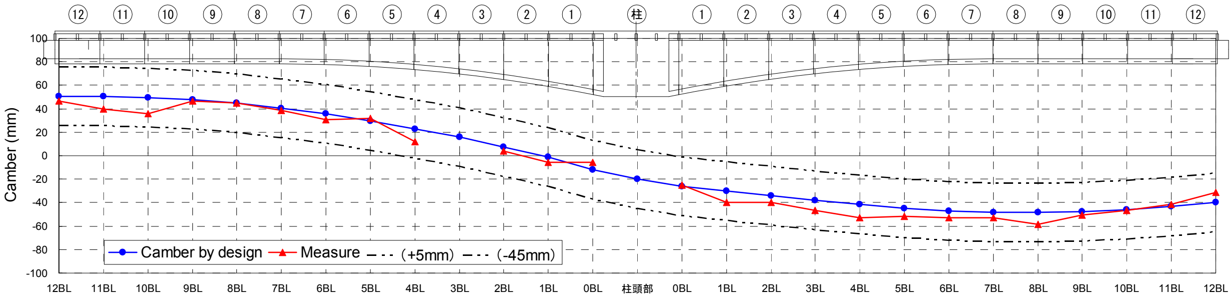

Fig.13 Girder camber of cantilever erection in P7

（3） Application to Construction

Deflection management in a cantilever erection

The influence of the temperature difference including the measurement of camber management by grasping the temperature difference of slabs, deflection quantity, and the occurrence time quantitatively was able to be reduced. If the cantilever erection length gets longer, influence to execute in setting height of the corrugated steel webs in the sunshine is big. Fig13 shows quantity of camber after last block erection of P7 pier cantilever erection. The height of the girder appearance in the cantilever erection end almost agreed with plan values. It may be said that it is the result that pushed forward execution while it is grasped, and reflecting influence by a temperature difference of slab that this precision was provided.

Closing of corrugated steel web

For the selection of span length that the bridge is unbalanced, as for the quantity of deflection change by the temperature difference at a tip of the corrugated steel web of P10 side greatest 30mm occurred (Fig.14). On the other hand, 2～3㎜ degree and a big difference occurred the quantity of deflection change of P9 side. On this account the situation that the deflection by temperature difference of slab didn't occurred was pursued in the joining of the corrugated steel web of a closure point (= welding work).

Because that the temperature difference of slab deflection gave influence by thermal storage of concrete in deflection convergence time had been grasped from a measurement result, bridge deck sprinkling was done since the day before. The work time that finished welding works by 8:00 a.m. when deflection by the temperature difference of slab began to occur was able to be got, and it was held down the deflection difference in closure to around 5mm, and by these, It was able to let upper and bottom flange reduce the secondary stress which occurred largely.

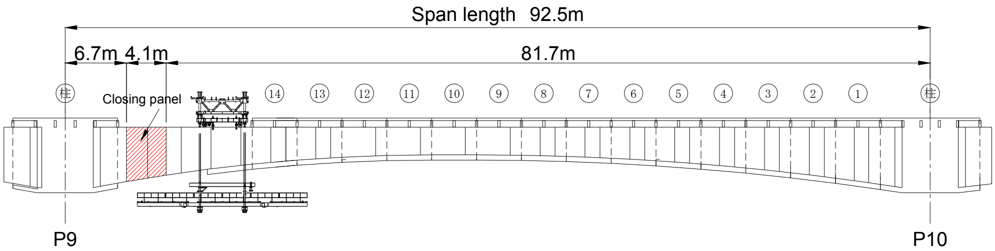

Fig.14 Side view (P9-P10)

9. AFTERWORD

This report introduced the result that carried out rationalization construction to use the corrugated steel web as construction members in the bridge having unbalanced selection of span length.
By this, cancellation of an unbalanced selection of span length and conversion of an effective moving vehicle were able to be planned.
In addition, construction of a side span in the steep topography was improved by this method, and labor saving of construction, cost reduction and process shortening were able to be planned.
In addition, influences of the temperature difference of slab or control by sprinkling are grasped by prior measurement, and there are a few examples to do camber management.
The bridge was the corrugated steel web bridge of span more than 100m, and the temperature measurement was carried out because the span was unbalanced, and by this, quantitative control of closure condition of the corrugated steel web was enabled in the bridge.
If contraction of the bridge becomes a help of a plan in a future similar PC bridge, I am happy.
All of you are thanked to a design of the bridge and the members whom it was taught to about execution concerned deeply last.

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